- VI.—*The Histology and Physiology of the Corpus Spongiosum and the Corpus Cavernosum, &c., &c.,* in Man.* By ALEX. W. STEIN, M.D., Attending Physician to Charity Hospital, Professor of Visceral Anatomy and Physiology in New York College of Dentistry and of Comparative Physiology, New York College of Veterinary Surgeons.

Histology.—The erectile tissue of the organ to which those parts belong may be said to consist of venous cavities or cells which freely communicate with each other, are continuous with the general venous system, and are lined with squamous epithelium. The direct connection of these cavities with the veins is clearly demonstrable in such preparations, in which the cavities are somewhat filled with blood (Fig. 8). In the corpus spongiosum these cells are quite large near the surface or immediately beneath the external fibrous investment, while toward the axis of the urethra they are short and narrow. In the bulb they are larger than at any part anterior to the same.

The interspaces between these cavities are occupied principally by non-striped muscles, which form, as it were, an external muscular tunic for these cavities. In these interspaces may also be recognized connective tissue forming the connecting medium of the muscles, blood-vessels, nerves, and lymphatics of the part.

The sheath of connective tissue, known as the albuginea of the corpus spongiosum, which lies beneath the subcutaneous areolar tissue, and which surrounds the corpus spongiosum in its entire length, is interspersed with innumerable fasciculi of organic muscles which are attached to or originate from the albuginea at innumerable and various points. From this origin they pass in a devious manner in the interspaces between the venous cells, inward toward the deeper portions of the spongy substance, verging suddenly from one direction into another, and by their manifold directions and connections with each other form the intricate trabecular structure or trellis-work of the corpus spongiosum.

Many of these fasciculi run horizontally internal to the albuginea, so that upon transverse section the periphery of the corpus spongiosum appears, at first glance, to be surrounded by a circular layer of organic muscles. Upon more precise examination, however, we find that this muscular layer does not form an absolute ring, but only an approximation to one. On the contrary, not a single fasciculus runs continuously around the spongy substance, but embraces only a small portion of its periphery in a horizontal direction,

* Illustrated by microscopical specimens prepared by my friend, John Busteed, M.D., and myself.

and that at those points where one fasciculus turns from one horizontal plane into another, others arise and continue in an analogous manner the horizontal course left by the first, and thus contributing to the formation of a more or less interrupted muscular ring upon the periphery of the corpus spongiosum.*

In the section of the corpus spongiosum before you can be seen the arteriæ profundæ corporis spongiosi, equidistant from the external fibrous covering and urethral canal in each lateral half of the corpus spongiosum. In this instance they are almost on a level with the urethra, though sometimes we find one artery a little below, the other a little above, the level of the urethra. At the bulbous portion we always find the arteries below the level of the urethra, because of the greater thickness of the parts below the canal at this part.

FIG. 1 (pp. 22 and 23).

THIN TRANSVERSE SECTION OF THE CORPUS SPONGIOSUM URETHRA. TAKEN FROM THE PENIS OF A MAN AGED TWENTY-SEVEN, MIDWAY BETWEEN THE GLANS AND BULBOUS PORTION. PREPARED IN ALCOHOL, AND TREATED WITH CARMINE. MAGNIFIED 20 DIAMETERS.

The albuginea, or external connective-tissue sheath of the corpus spongiosum, is shown at A A' A'' A'''. The upper half, which is connected with the corpus cavernosum, is seen at A A' A''; the lower half at A, A'', A'. It is abundantly interspersed with (dark) fasciculi of organic muscles, *a, a, a, a*, which do not run completely around the periphery of the corpus spongiosum, but form only fragments of a muscular ring. These fasciculi are continuous with those seen in the substance of the corpus spongiosum at B, B, B, B. At *A**, *A†* (between A and A'), may be seen such fasciculi, extending from the albuginea directly into the substance of the corpus spongiosum. At *b, b, b*, can be seen the cut surfaces of a large number of muscular bundles appearing as round, oval, or irregularly-shaped dark spots. At *c, c, c, c*, may be seen other muscular fibres running in continuity. The latter run in a parallel direction with the section, while the former run in a vertical direction, and are consequently cut by the section. Between these bundles of muscles can be seen, *d, d, d, d*, innumerable empty spaces or meshes of irregular shape. The walls of these spaces have become separated in preparing the specimen, while during life they are generally in immediate contact. These spaces are lined with pavement (Pflaster) epithelium, which can be distinctly seen, in suitable preparations, with a magnifying power of 60 to 200 diameters. Some of these meshes are quite near the mucous membrane, separated from it only by a thin layer of connective tissue, *i. e.* in the upper wall of the urethra in this figure. Transverse section of the corpus spongiosum will show as a rule two large arteries, *e e'*, the arteriæ profundæ corporis spongiosi. Each of these is surrounded by a number of organic longitudinal muscular bundles, *e**, *e**, which appear as round masses, in whose centre the artery passes. In the middle of the section is seen an empty space, C, the canal of the urethra. The epithelial covering of the mucous membrane is indicated at *f, f, f*, and is seen extending into its lacunæ. The existence of a real space in the accompanying figure is the result of the preparation. It does not exist during life. At *g, g', g'', g†, g**, is seen the cut surface of a lacuna which extends deeply into the substance of the corpus spongiosum at *g**, and sends off several branches from its sides *g', g'', g†*. The largest meshes are at the external portions of the corpus spongiosum; the smaller ones near the urethra. The substance of the corpus spongiosum near the urethra is more transparent than the rest, because it consists of finer fibres than the parts more external.

* B. Stilling, 'Harnröhren-stricturen,' Fig. 1.

FIG. 2.

LONGITUDINAL SECTION FROM THE SUPERFICIAL PARTS OF THE CORPUS CAVERNOSUM (MAN). ALCOHOL PREPARATION, TREATED WITH CARMINE, ACETIC ACID, AND GLYCERINE. MAGNIFIED 15 DIAMETERS.

This figure represents the trellis-work of the corpus spongiosum formed by the manifold directions and interlacing of its muscular fibres.

According to Müller, there are two sets of arteries, differing from one another in their size. The first are the *rami nutritii*, which are distributed upon the walls of the veins and throughout the spongy substance, differing in no respect from the nutritive arteries of other parts; they anastomose freely with each other, and terminate in capillaries. The second set he calls *arteriæ helicinae*, from their supposed resemblance to the tendrils of the vine. They are given off from the larger branches as well as the smaller twigs of the arteries. They are especially to be seen in good longitudinal sections, sending out short branches somewhat like a ram's horn, several going off from one point in a stellate form, or as the arms of a chandelier, and terminating in an expanded or knob-like extremity, which project freely into the venous cavities (Fig. 5). They are not entirely naked, but are covered with pavement epithelium. These arteries are more easy of detection in the corpus

FIG. 3.

THIN TRANSVERSE SECTION OF THE CORPUS SPONGIOSUM (MAN), PREPARED IN ALCOHOL. TREATED FIRST WITH CARMINE, AND AFTERWARD WITH ACETIC ACID, AND PRESERVED IN GLYCERINE. MAGNIFIED 160 DIAMETERS.

In the centre of the picture at *a*, is seen a transverse section of the arteriæ profundæ corporis spongiosi. At *b*, the inner coat of the artery. At *c*, *c*, its very darkly-stained middle coat, with the nuclei of its individual muscular fibres. At *d*, *d*, its transparent external connective-tissue coat. The artery is surrounded by quite a number of organic muscular bundles, like a tube surrounded by a bundle of staves, *e*, *e*, *e*, *e*. At many points may be seen a portion of these fasciculi connecting and mixing with the muscular coat of the artery, as, for example, at *e**. The muscular bundles surrounding the arteries are so distinct from the other longitudinal muscular bundles that they must be recognized as a set belonging exclusively to the arteries. The meshes of the spongy substance, *g*, *g*, *g*, are seen to be lined by pavement epithelium, *h*.

cavernosum than in the corpus spongiosum. In the latter body they are most numerous in the bulbous and posterior portions.

In most of these terminal knobs can be seen a triple fissure, the form of a *Y*—like the three-horned figure in the crystalline lens of the human eye (Fig. 7). The smaller branches often present but a simple transverse fissure. Stilling is inclined to regard these fissures as the openings or mouths of the arteries, which are closed in the ordinary condition, but in the state of erection are opened and empty the arterial blood into the venous cavities or cells.

FIG. 4.

THIN LONGITUDINAL SECTION OF THE CORPUS SPONGIOSUM (MAN). PREPARED IN ALCOHOL, AND TREATED WITH CARMINE. MAGNIFIED 160 DIAMETERS.

In the centre of the figure is seen a branch of the *arteria profunda corporis spongiosi*, *a, a*. It is accompanied upon both sides by organic longitudinal bundles of muscles, *b, b, b, b*, which are seen running for some distance in continuity near the artery. Some of these fasciculi pass directly into the walls of the artery, as at *, *, *, and are inserted in the same. Transversely-running muscular fasciculi, *c, c, c*, as well as those which bend from the longitudinal to the transverse direction, *d, d, d*, are very distinct. Also the meshes between these fasciculi, *g, g*.

These arteries are accompanied by a special system of longitudinal bundles of muscles, whose fibres become inserted at various points into the middle coat of these vessels. Stilling, I believe, was first to call attention to this anatomical fact. These bundles may be seen in both transverse and longitudinal section (Figs. 3 and 4). The number and size of these bundles vary in different sections, in consequence of the changes which they undergo by the insertion of their fibres into the walls of the arteries on the one hand, and again by the addition of new fibres to these bundles from other planes.

The bundles accompanying the large arteries are comparatively numerous, while those accompanying the smaller ones are few, and not so distinct.

FIG. 5.

THIN LONGITUDINAL SECTION FROM THE POSTERIOR PORTION OF THE CORPUS CAVERNOSUM (MAN). MAGNIFIED 15 DIAMETERS. THE ORGAN WAS INJECTED THROUGH THE ARTERIA DORSALIS WITH BEALE'S BLUE FLUID, AND THEN HARDENED IN ALCOHOL. THE THIN SECTION WAS AFTERWARD TREATED WITH CARMINE, ACETIC ACID, AND GLYCERINE.

In the centre of the figure is seen the artery, *a, a*, running from below upward. The dark injection in its cavity is well shown. From the right and left of this artery are given off the arteriæ helicinæ, *b, b, b, b*. They assume different forms. Their terminal knobs lie free in the meshes, *b* b**, and are covered with pavement epithelium, which by higher magnifying powers are very distinctly brought into view.

The knobby terminations of these arteries possess muscular fibres closely packed in concentric circles, which probably act as sphincters to the mouths of these vessels.

There is one other anatomical fact mentioned by Stilling, to which I will briefly refer, on account of its pathological bearing.* It is the intimate relationship of the epithelial elements of the urethra with sub-mucous tissues of the corpus spongiosum.

That certain epithelial cells possess prolongations by which they are in intimate connection with the underlying tissues, Stilling

* This I will reserve for another occasion when I shall have completed some observations now engaged in.

FIG. 1.

THIN TRANSVERSE SECTION OF THE CORPUS SPONGIOSUM URETHRA. (*See page 17.*)

FIG. 6.

PART OF A FINE LONGITUDINAL SECTION FROM THE POSTERIOR PORTION OF THE CORPUS CAVERNOSUM (MAN). PREPARED IN ALCOHOL, AND TREATED WITH CARMINE. MAGNIFIED 160 DIAMETERS.

In this section the artery *a, a*, is seen running along the entire length of the section, sending off a number of branches which terminate in thickened ends, *c, c, c*. The red knob-like ends of this artery are quite conspicuous in consequence of the imbibition of carmine. To the left of the artery is seen the course of a longitudinal muscular bundle, *d*, which is inserted in the upper third of the artery. Transverse and oblique muscular bundles are seen at *e, e*.

FIG. 7.

THE KNOB-LIKE END OF AN ARTERIA HELICINÆ FROM A FINE LONGITUDINAL SECTION OF THE CORPUS CAVERNOSUM (MAN). PREPARED IN ALCOHOL, AND TREATED WITH CARMINE.

The terminal end *a* appears to lie free in one of the meshes. The mouth of the vessel is seen at *, which appears as a Y-shaped fissure.

claims to have indicated as early as 1857, since which time his statements have become confirmed by the researches of others, who have represented the passage of nerve fibres to the epithelial layers of certain tissues, as for example in the cornea.* He affirms that the epithelial cells of the urethra are in manifold connections with the muscular fibres, nerves, and other tissues of the corpus spongiosum. "The most superficial cells," he says, "terminate in a pedicle or filiform prolongation, which often remain connected with the mucous membrane after the body of the cell has separated from its connections. A good longitudinal section will often show three or four of such cells, one above the other, hanging like pears by their stalks, the cells directed toward the bladder, the stalk toward the external meatus. To state the precise manner in which these connections occur is reserved for future research. Especially will it

* Frey, 'Handbuch der Histology und Histochemie,' 3. Aufl., Leipzig, 1870, p. 608.

have to be ascertained whether certain epithelial cells of the urethral mucous membrane are real terminations of nerves, and others real terminations of muscular fibres. If we consider the extreme sensitiveness of the epithelial layer of the healthy cornea to the contact of ever so fine a foreign body; if we consider that the most superficial contact of the point of a needle with the cornea produces the most severe pain and reflex movements; while, after destruction of the most superficial layer at one point, the needle produces at that point only an inconsiderable amount of pain—facts which every physician has opportunity to observe in removing foreign bodies (dust, iron filings, particles of coal, &c.) from the cornea—the conclusion is almost irresistible that the epithelial covering of the cornea consists of cells which are to be regarded as nerve terminations.

Physiology.—The cause and mechanism of erection may be said to depend upon two phenomena occurring simultaneously:—

1. Upon an increased influx of blood through the arteries which empty by the arterial helicinae into the venous cavities.
2. Upon mechanical pressure affecting the veins which convey the blood from the penis, whereby a retardation of the venous circulation is induced.

In the passive condition of the penis the same quantity of blood flows to and from the organ, but during erection the entire arterial system becomes distended, especially those known as the arteriæ helicinae become actively dilated, and empty themselves into the venous cavities. The dilatation of these vessels is supposed to be effected through the agency of the special system of longitudinal bundles of muscles which accompany, and whose fibres are inserted into the walls of these arteries.

The muscles chiefly concerned in arresting the efflux of blood, or at least preventing it from being as great as the influx, are the acceleratores urinæ and erectores penis.

The contraction of the acceleratores urinæ muscles impedes the return of blood through the vena corporis spongiosi, by pressure upon the bulbous portion of the corpus spongiosum.

The erectores penis act as erectors, by compressing the crura and vena dorsalis. They embrace the root of the penis and compress it. The pressure upon the vena dorsalis impedes the return of blood by this vessel, and the pressure upon the crura produces the same effect upon the veins of the corpus cavernosum.

The transversus perinei probably assists the posterior fasciculi of the acceleratores urinæ in producing turgescence of the corpus spongiosum, by virtue of its insertion into the fibrous tunic of the bulb.

These muscles are supplied with nerves by the pudic branch of the sacral plexus, and it is an interesting fact, capable of demonstration upon the lower animals, that after division of this nerve the penis is incapable of erection.

FIG. 8.

TRANSVERSE SECTION OF THE CORPUS CAVERNOSUM (MAN). PREPARED IN ALCOHOL, TREATED AT FIRST WITH CARMINE, AND AFTERWARD WITH ACETIC ACID AND GLYCERINE, AND PRESERVED IN FARRANT'S LIQUOR. MAGNIFIED 160 DIAMETERS.

The object of this figure is to represent the communication of the veins with the meshes of the corpus cavernosum (and spongiosum). The dark portion of the picture indicates the corpus cavernosum, *a, a*, the lighter portion the albuginea of the corpus cavernosum, *b, b, b*. The meshes are all filled with blood, in consequence of which the structure of this part appears considerably more distinct than when these cavities are empty. Internal to the albuginea of the corpus cavernosum are seen a large number of veins, *c, c, c*, forming a plexus. The direct connection of some of these veins with the meshes of the corpus cavernosum can be seen at *, *.

In the passive condition the natural tonicity of the muscular trellis-work of the penis is sufficient to maintain the walls of the venous cells in apposition; and they, together with the sphinctoric action of the circular fibres around the mouths of the arterial helicinae, prevent the flow of blood into these cells. But, when the parts are stimulated to erection, the muscular bands are obliged to yield to the distending force of the blood (according to Müller, it appears that the blood accumulating in the penis during erection is subjected to a pressure equal to that of a column of water six feet in height). The meshes become filled, and remain so until the stimulus to erec-

FIG. 8.

Fig. 8—*g, h, i, j, k, l*—represents the various shapes of the arteriæ helicinæ, which are frequently found in injected preparations of the corpus cavernosum. Magnified 15 diameters.

The description of the plates is taken from 'Die Rationelle Behandlung der Harnröhren-stricturen,' by Dr. B. Stilling.

tion subsides, when the acceleratores urinæ and erectores penis muscles relax, and remove the pressure from the veins. The trabeculæ (non-striped muscles) of the penis now contract and expel the blood from the dilated venous cells.

The contractile force of the corpus spongiosum is well displayed in persons who, for the first time, submit to the introduction of a catheter or sound into the urethra; the entrance of the instrument is often sensibly opposed, and during withdrawal it is forcibly expelled.

This phenomenon cannot be attributed entirely to the action of the acceleratores urinæ and compressor urethræ muscles, for it is manifest even within an inch of the external meatus.

The action of the muscular trellis-work of the corpus spongiosum, as it affects micturition and the ejaculation of the spermatic

fluid, is of interest. During micturition the entire corpus spongiosum, as well as the urethra, becomes somewhat stretched. At the end of micturition the tonicity of the trellis-work is sufficient to coaptate the walls of the urethra, and to expel the last drops of urine which may remain in the anterior portion of the canal. This pressure is strongest at those parts where the urethra and its surrounding meshes are narrow; and weakest where these cavities are wide, and consequently more dilatable, as at the bulb.

As the external fibrous investment of the corpus cavernosum consists of broad, thick bands of connective tissue, it becomes firmer, harder, and more unyielding during erection, than the corpus spongiosum. The latter being smaller in circumference, with its external fibrous investment interspersed with non-striped muscular bands, it remains even during the most complete erection, and during the ejaculation of the sperm, sufficiently dilatable or distensible to permit the seminal fluid to flow through the canal. Should the corpus spongiosum attain that degree of hardness which the corpus cavernosum acquires, the canal would not yield to the pressure of the sperm, and ejaculation would be obstructed.

The pressure which the corpus spongiosum is capable of exerting upon the urethra becomes quite considerable, when to the natural tonicity of its muscular trellis-work above mentioned there is added a special stimulus to contraction, which obtains when the penis is brought to a state of erection. Each new pulsation increases the quantity of blood in the meshes or venous cavities, and this—as it were—supplementary body within these cavities stimulates the muscular bands to increased activity. The pressure now brought to bear by these bands very materially assists the *acceleratores urinæ* and *compressor urethræ* muscles in communicating an expulsive impetus to the outflowing stream of urine or seminal fluid.

The greater the special force exerted by the contraction of the *acceleratores urinæ* during ejaculation, the more is the erection of the penis augmented, and the concentric pressure of the muscular trellis-work upon the spermatic fluid increased.

For this reason micturition is so difficult during complete erection, and *immediately after* ejaculation.

Thus I have endeavoured to lay before you, in a somewhat condensed form, a synopsis of some views at present entertained upon the histology and physiology of the penis. This subject is but imperfectly understood; its literature is meagre, and much of that which has been written is vague and unsatisfactory, while many points have remained entirely unexplored. Yet there are few subjects which present a more fruitful field for histological investigation than the one to which I have now had the honour of calling your attention.—*Read before the New York Dermatological Society.*